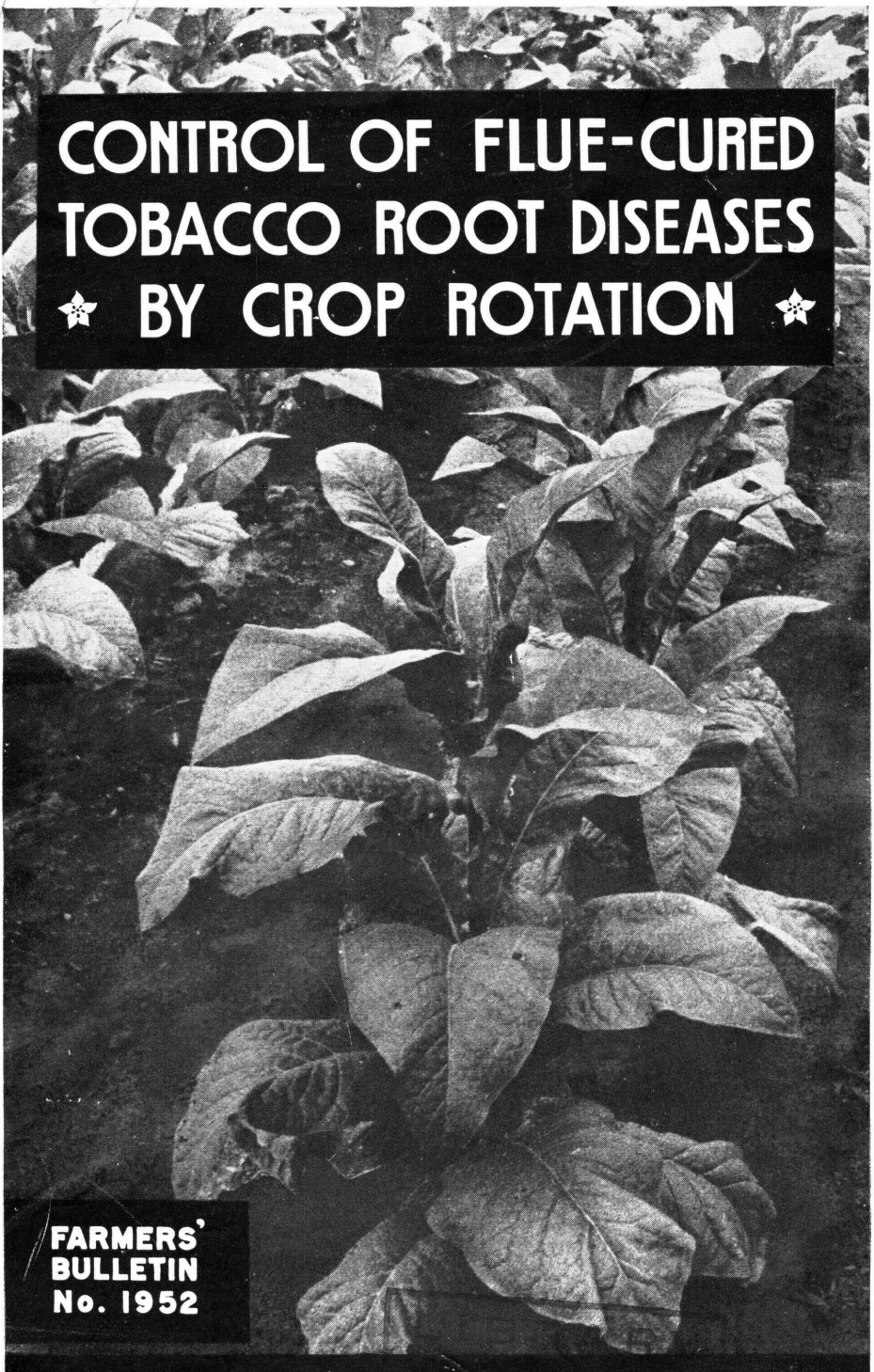
CONTROL OF FLUE-CURED TOBACCO ROOT DISEASES BY CROP ROTATION



FARMERS' BULLETIN No. 1952

U. S. DEPARTMENT OF AGRICULTURE

DISEASES caused by parasites that live over in the soil are serious crop hazards for the growers of flue-cured tobacco. Rotation of crops is an important method of reducing these losses, and in some cases it is the only one that is now practicable, particularly in a critical period of manpower shortage.

To rotate crops effectively, however, it is necessary to distinguish between different diseases, because no one intermediate crop is equally effective in combating all the soil-borne diseases of tobacco. Corn is very helpful in controlling wilt, and peanuts aid greatly in reducing root knot damage.

The root diseases of flue-cured tobacco can be identified by observing the general appearance of an infected field and then examining individual plants. Based on information available on the disease-control value of common crops that can be grown in the Southeast between crops of tobacco, intelligent rotation will be of immediate and practical benefit to tobacco production by reducing disease losses. At the same time the practice will facilitate the production of important feed and food crops.

Washington, D. C. March 1944

CONTROL OF FLUE-CURED TOBACCO ROOT DISEASES BY CROP ROTATION

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Contents

ROTATION of crops reduces the occurrence of soil-borne diseases of tobacco. This is well known. It is easy, however, to confuse some of these diseases, and, unfortunately, different crop rotations are not equally effective with all.

The purpose of this bulletin is to show briefly how to identify certain of the diseases and then to summarize the results in control that were obtained from rotation experiments conducted cooperatively by the United States Department of Agriculture and the several States, at the Coastal Plain Experiment Station, Tifton, Ga.; the Pee Dee Experiment Station, Florence, S. C.; the McCullers Branch Station, Raleigh, N. C., and the Tobacco Branch Station, Oxford, N. C.

Six root diseases and their causal organisms that raise serious problems for flue-cured tobacco growers in the Southeast are the following:

Root knot	*Heterodera marioni.*
Black shank	*Phytopthora parasitica* var. *nicotianae.*
Bacterial, or Granville, wilt	*Bacterium solanacearum.*
Fusarium wilt	*Fusarium oxysporum* var. *nicotianae.*
Southern stem rot	*Sclerotium rolfsii.*
Sore shin	*Rhizoctonia solani.*

Considerable variations may occur in the appearance and development of these diseases; only the typical and more commonly observed symptoms are described. As one becomes familiar with the more readily discernible symptoms, other helpful aids to identification will be found. Also there are experts in the tobacco areas from whom growers can obtain assistance. More detailed information regarding two of these diseases has recently been published by the United States Department of Agriculture.[2] [3]

[1] The recommendations made by the authors are based on experiments conducted in cooperation with the Georgia Coastal Plain Experiment Station and State College of Agriculture, the North Carolina Department of Agriculture, and the agricultural experiment stations of North Carolina and South Carolina.

[2] BULLOCK, J. F., and MOSS, E. G. STRAINS OF FLUE-CURED TOBACCO RESISTANT TO BLACK SHANK. U. S. Dept. Agr. Cir. 682, 9 pp., illus. 1943.

[3] SMITH, T. E. CONTROL OF BACTERIAL WILT (BACTERIUM SOLANACEARUM) OF TOBACCO AS INFLUENCED BY CROP ROTATION AND CHEMICAL TREATMENT OF THE SOIL. U. S. Dept. Agr. Cir. 692, 16 pp., illus. 1944.

DISEASE IDENTIFICATION

Root knot.—This disease is so easily recognized (fig. 1) that a detailed description is not required. The characteristic symptom is swollen, knotted roots that decay late in the season, with the result that the plants are weak and throw out few or no suckers. Stunted growth, together with signs of malnutrition, excessive wilting on hot dry days,

Figure 1.—Root knot: Diseased tobacco root.

and premature leaf ripening usually are associated with the disease. Leaves harvested from severely affected plants frequently are trashy when cured, but diseased plants often live long enough to yield normal crops. When severe root infections occur early in the season and when there is continuous infection of newly developed roots, the plants may die before the end of harvest.

Black shank.—This destructive disease is becoming more widespread each year. At present it occurs in the flue-cured tobacco areas of Virginia, both western and eastern North Carolina, Georgia, and Florida. The first symptom, a sudden wilting of the entire plant, is

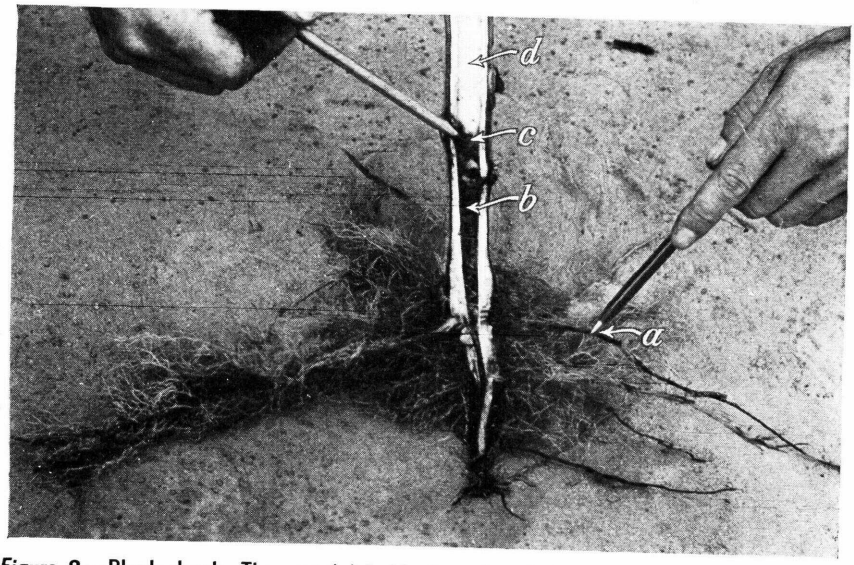

Figure 2.—Black shank: The root (*a*) is blackened and dead and the diseased pith (*b*) has separated into disks. The pencil on the left points (*c*) to the upper margin of the disease in the stem, and above this the pith and wood (*d*) are clean and white; contrast this with the dark streaks in the stem wood and adjacent pith of the plant affected by bacterial wilt (fig. 4).

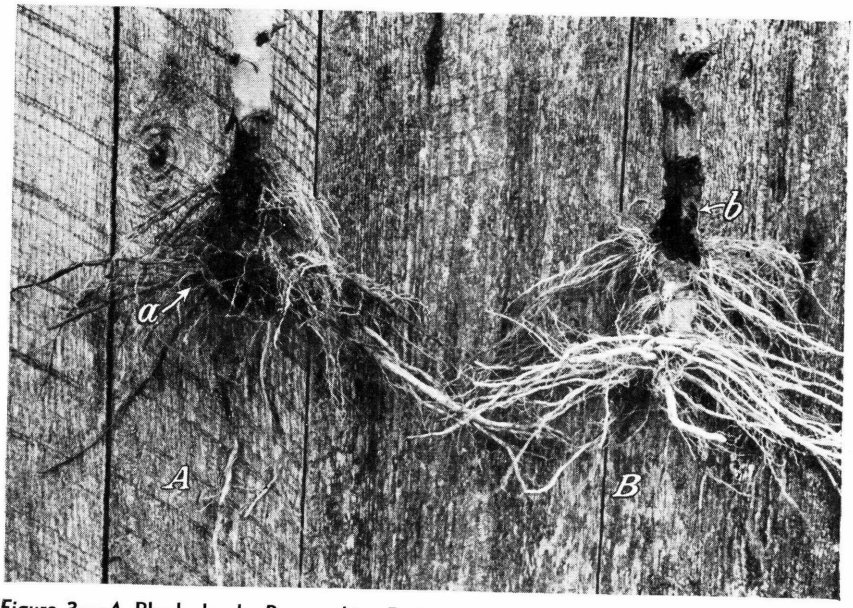

Figure 3.—*A*, Black shank; *B*, sore shin: Both plants were completely wilted. The black shank infection began in a root in region (*a*) and spread up into the base of the stem and out along the roots on the other side of the plant. The sore shin began in the stem near the ground surface in region (*b*) and spread up the stem but not down into the roots.

soon followed by death. On examination of plants just beginning to wilt, one or more of the larger roots will be found blackened and dead. Soon afterward all the roots are killed and the blackish decay then spreads to the base of the stem (figs. 2 and 3). Large diseased plants at this stage will show the pith separated into disklike layers (fig. 2).

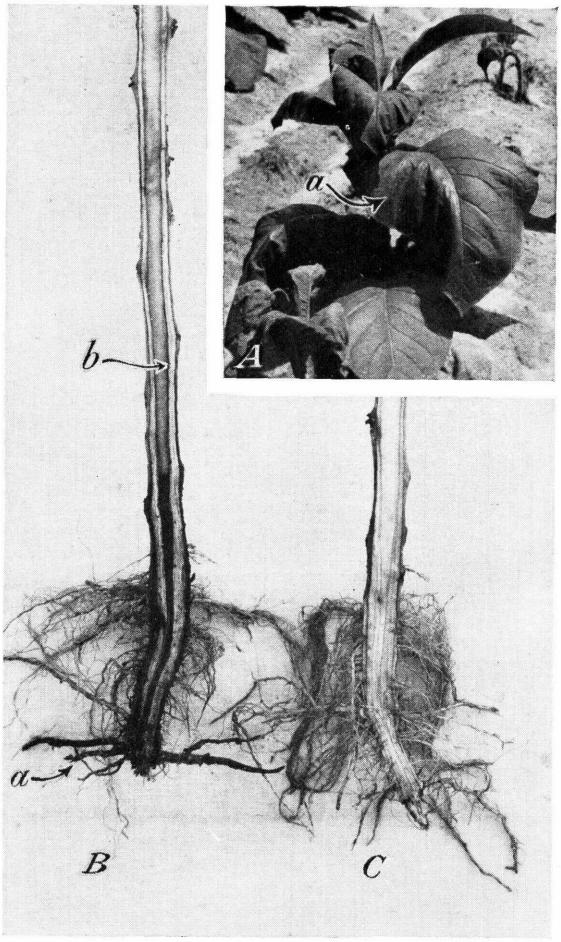

Figure 4.—Bacterial wilt: *A*, Young plant, showing the one-sided wilting of green leaves (*a*) characteristic of the disease early in the season. *B*, Diseased plant, with decayed roots (*a*) and dark streaks (*b*) in the wood next to the pith that extend well up the stem. *C*, Uninfected healthy plant.

An affected field may have badly diseased areas where practically all the plants are wilted or dead and other areas where there are no signs of disease. The infection is easily spread by water, and for this reason the lower parts of a field usually are severely affected.

Bacterial wilt.—This entirely different yet very destructive disease, known also as Granville wilt, is found in South Carolina and Georgia occasionally, and in North Carolina and Virginia it occurs throughout

the flue-cured area. It is most destructive in the Henderson-Oxford-Durham section. The diseased plants, usually grouped in definite field areas, show wilting and decay of the roots, much as in the case of black shank. The most easily recognized symptom in young plants is the wilting on one side of the plant of leaves still green (fig. 4). In larger, older plants, wilt can be identified by slicing the stem lengthwise for a distance of 1 to 2 feet above the ground, where dark-brown to black threadlike streaks will be found in the woody part.

Fusarium wilt.—This disease is relatively new to the flue-cured areas, but it is already common in the Whiteville-Chadbourne section of North Carolina, and has occurred to a limited extent in South Carolina and Georgia. It sometimes resembles bacterial wilt, but affected plants wilt much more slowly. The first symptom is yellowing of leaves on one side of the stalk, with no wilting, but the growing bud usually turns yellow and then bends toward the affected side of the plant. This condition may continue for some time before decided wilting or death results. The disease can be identified further by removing the soft outer part of the bark from the affected stem, where the surface of the wood will be found to be brown (fig. 5).

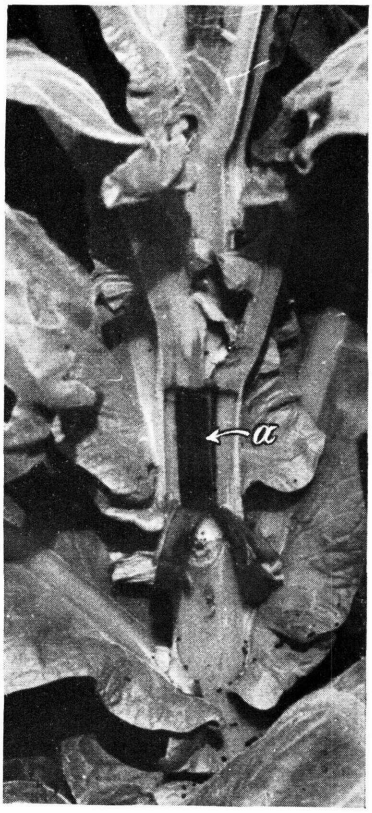

Figure 5.—Fusarium wilt: Stem with a section of the soft outer bark removed to show the dark-brown layer (*a*) just below.

Southern stem rot and sore shin.—These two similar and common diseases of flue-cured tobacco are widely distributed. Though much less destructive, they may sometimes be confused with bacterial wilt and black shank. Affected plants usually die rather suddenly, but it is rare to find more than 5 percent of a stand with stem rot or sore shin. Diseased plants occasionally may be grouped together, but more often they are scattered singly over the entire field. In this latter respect these diseases differ from bacterial wilt and black shank, which usually affect groups of plants in one or more parts of the field. Infections are most noticeable just before and during the period of harvest, and from the beginning until the close of harvest the number of affected plants progressively increases. On mature plants the leaves suddenly turn yellow, wilt, and die. On examination the stalk usually will be found dead and dried near the ground surface, and in the case of southern stem rot, small round amber-colored bodies (fig. 6) will be seen adhering to the dead area. In moist weather a white cottony fungus growth may also be present. The infection seldom extends up into the stalk more than a few inches, but it may

affect part or all of the root. Affected stems are light brown, and amber-colored bodies and white fungus growth may also be observed on roots. Sore shin is very similar to stem rot except that the small

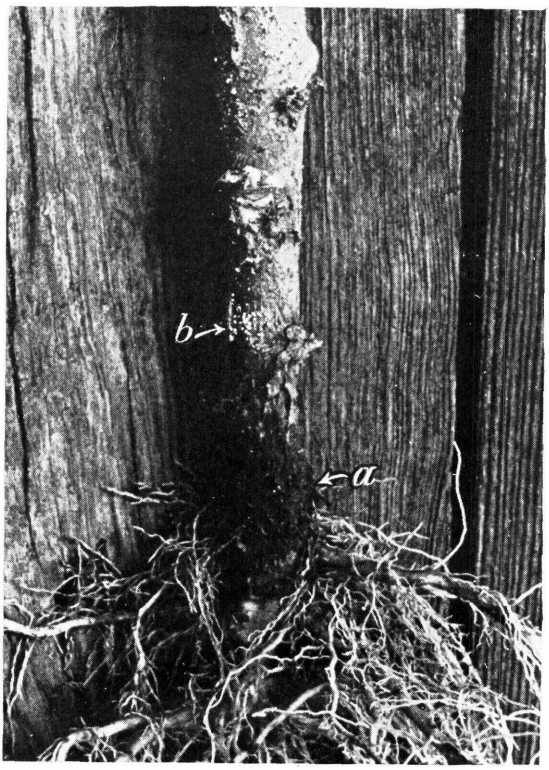

Figure 6.—Southern stem rot: Decay began at the ground surface (a), and the roots are still healthy. The small seedlike bodies (b) that definitely identify this disease are very young and light-colored; later they become dark brown.

round bodies are absent. Affected plants fall over very easily, the diseased stems are a very dark brown, and the decay is usually restricted to the stem. The roots do not die until the above-ground parts of the plant die (fig. 3).

KEY TO DISEASE IDENTIFICATION

General field appearance	*Most distinctive symptoms*	*Disease*
Plants stunted to varying degrees; rarely killed except late in season—field occurrence general.	Swollen knotted roots (fig. 1)	Root knot.
Plants killed suddenly—disease concentrated in definite parts of field.	Decay begins in root and spreads rapidly to destroy all roots and base of stem; both stem and roots blackened; discoloration does not extend up into stem beyond the dead part (figs. 2 and 3).	Black shank.
Plants may be killed suddenly—grouped ir definite parts of field.	Decay begins in roots and spreads to destroy all roots, but does not rapidly destroy base of stem; black discoloration in roots extends well up into stem as black streaks in woody parts (fig. 4).	Bacterial wilt.
Plants may be killed suddenly—affected plants are more often scattered over field.	Decay begins in stem at ground surface or in roots; affected part of stalk or roots brown; discoloration does not extend up into stalk; small round bodies present at base of stalk or on affected roots (fig. 6).	Southern stem rot and root rot.
	Similar to above but no round bodies present on affected part of stalk, which is very dark brown; roots not generally affected (fig. 3).	Sore shin.
Plants usually killed slowly—may or may not be grouped in definite parts of field.	Leaves on one side of plant turn yellow, slowly wilt, and die; solid brown discoloration on surface of stem wood just beneath the outer bark, extending all the way from roots to affected leaves (fig. 5).	Fusarium wilt.

DISEASE CONTROL BY ROTATION

ROOT KNOT

Extensive tests have shown that effective root knot control can be attained in 3-year rotations with Spanish peanuts and oats or rye. Allowing land to grow up to weeds for 2 years or more is very helpful (fig. 7), but less profitable than using cultivated crops. Crotalaria and runner peanuts are highly effective in preventing the disease, but these and other soil-building crops must be used judiciously in flue-cured tobacco rotations, as some of them add too much organic nitrogen for the production of good quality flue-cured leaf. The influence of legume rotations on quality is discussed under the heading "Rotation in Relation to Yield and Quality." Cotton, corn, and such hay crops as root knot resistant cowpeas (Iron and Brabham) and soybeans (Laredo and Biloxi), while rarely showing root knot damage, do not actually reduce nematode populations in the soil, and hence these are not good crops to precede tobacco on infected land. They can often be included safely in the same rotation, however, by placing a more resistant crop before the tobacco. Thus, cotton the first year, peanuts the second, and tobacco the third has proved successful. Another good crop combination for a 3-year rotation

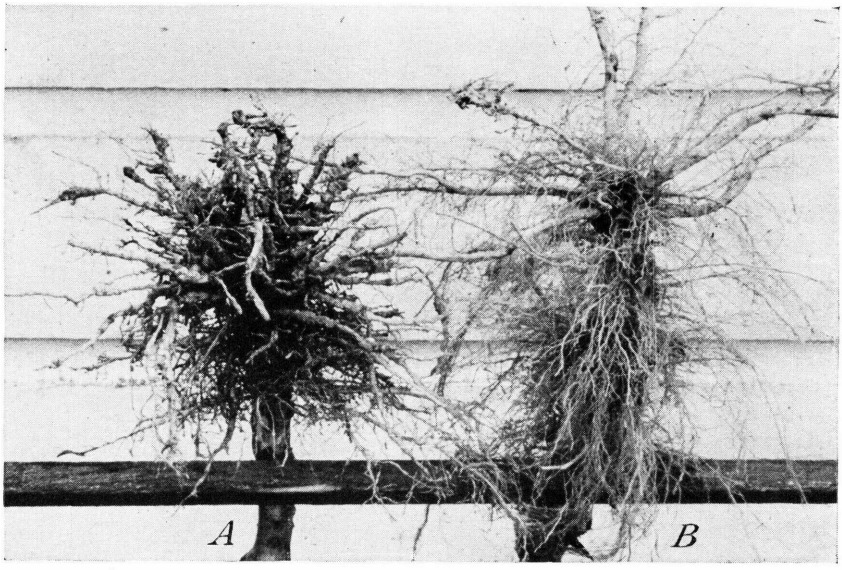

Figure 7.—Root knot control by rotation: *A*, Tobacco grown after cotton; *B*, tobacco grown after weeds. Rotation with such crops as cotton and corn does not control root knot.

is peanuts or crotalaria the first year, oats followed by weeds the second, and tobacco the third. In moderately contaminated areas a 2-year rotation may sometimes be sufficient, whereas heavily infected fields in the deep South sometimes require a 4-year system.

Winter cover crops of oats or rye have often increased the value of tobacco crops produced on root knot infected land by about $50 an acre, the increase usually being in proportion to the quantity of organic matter turned under. The cover crops appear to reduce the damage somewhat without actually reducing the incidence of the disease. Growing flue-cured tobacco after winter crops of Austrian Winter peas usually increases the damage.

BLACK SHANK

Black shank can be controlled by a rotation in which any of the common crops can be used except potatoes, peppers, tomatoes, and eggplant. This rotation is very different, however, from that for the control of root knot. Success in root knot control requires merely that infection be reduced or kept down to a minimum, while in black shank it is necessary for it to be practically eliminated. The minimum rotation that can be recommended for an infected field is 4 to 5 years of other crops, coupled with adequate protection against recontamination.

The organism causing black shank multiplies and spreads with extreme rapidity, and a single infection is enough to kill an entire plant. The nature of the organism makes it possible for it to be carried with great ease by water, and hence one tobacco field must be protected against contaminated drainage water from another. The disease is also spread at transplanting time by using water on the

Figure 8.—Black shank infected field near Stokesdale, N. C., 25 percent destroyed in 1942. In the previous year only a few diseased stalks were in the immediate foreground.

seedlings from ponds or streams that have received drainage from infected fields. Other sources of infection are diseased plant beds and contaminated scrap tobacco and manure.

In beginning a rotation it is desirable to reduce chance spread of infection to other parts of the same farm by seeding the infected field to grass, clover, lespedeza, or small grains. These crops require no cultivation and also reduce washing. Peanuts, corn, cotton, and other crops can then be grown for the 2 years preceding the next crop of tobacco.

By careful rotation, infection can be reduced to such a degree that a successful crop of tobacco can be produced. The disease will not be completely eliminated, however, so it is not advisable to plant such fields to tobacco 2 successive years (fig. 8).

BACTERIAL WILT

Rotation is a valuable control measure for bacterial wilt, but even the best rotation is not always satisfactory under all conditions. A number of common crops in addition to tobacco are susceptible to wilt, and for this reason potatoes, peppers, tomatoes, and peanuts should not be used on wilt-infected land. Also, diseased land left to weeds for several years usually produces a badly diseased crop of tobacco. Corn has been the most effective of the many crops tested for eliminating wilt infection from the soil. Redtop, small grains, and lespedeza also were satisfactory, and, contrary to early reports, cowpeas, soybeans, and velvetbeans are not subject to wilt and can be used to advantage in the rotations, particularly on poor, sandy soils deficient in organic matter and nitrogen. In general, these crops should be grown on wilt-infected land for 2 or 3 years before it is again planted to tobacco.

FUSARIUM WILT

The results of the rotation experiments conducted in different localities indicate that whether this serious disease becomes widespread will depend on the care with which tobacco growers rotate their land. Fusarium wilt of flue-cured tobacco is caused by a strain

of the organism that causes a similar disease of sweetpotato, and has made its appearance on tobacco grown in rotation with that crop. In one case more than 10 years elapsed before this happened, and in another, the disease appeared in the first tobacco crop grown after sweetpotatoes. Once established in tobacco, this wilt can easily carry over from one crop to another. For this reason it is strongly recommended that tobacco and sweetpotatoes be not grown in the same rotation. Since there is no known control for this wilt, the safest practice is never to plant them on land to be used for tobacco.

SOUTHERN STEM ROT AND SORE SHIN

All the evidence from extensive experiments indicates that rotation has little influence on the occurrence of southern stem rot and sore shin. These diseases rarely kill more than 5 percent of the plants in a field, and records over many years show that the percentage of infected plants fluctuates from year to year. Strangely, the cultivation of tobacco in rotation with stem-rot susceptible crops, as peanuts and soybeans, has not resulted in any increase in the incidence of these two diseases. Consequently, they need not be considered in planning disease-control rotations.

SOME PRACTICAL ROTATION PROBLEMS

Since the control of different diseases requires for each a different type of crop rotation, the question naturally arises as to what to do for a combination of diseases. In actual practice, however, the question seldom does arise, except in limited areas, because one particular disease is almost always the major problem, and this decides the type of rotation. Thus, if the major problem is root knot, a 3-year rotation with peanuts, crotalaria, oats, or weeds is suggested; if bacterial wilt, a 3- or 4-year rotation with corn, cotton, soybeans, and grasses is suggested, while peanuts and weeds should be avoided. Although both diseases are of widespread occurrence, they are not often serious on the same farm. Where both do occur, however, cultivation of cotton or corn or crotalaria for 2 years, followed by oats the third, and tobacco the fourth year promises to be a successful rotation for the prevention of both. On thin, sandy lands crotalaria could be included after the oat crop. This same rotation extended over a 5-year period would also be a good cropping system where black shank, root knot, and bacterial wilt are present in the same field. Since oats and crotalaria are more resistant to root knot than cotton or corn, one of the former should be grown immediately in advance of tobacco, especially where root knot is expected to be severe.

Another question that often arises is whether rotations shorter than the ones here recommended can be used. From the viewpoints both of controlling soil-borne diseases of flue-cured tobacco and of producing other profitable field crops, almost any rotation is superior to none. Thus, on root knot infected land, crop rotation with cotton is better than continuous cultivation of tobacco. Furthermore, alternation of tobacco and harvested peanuts may often give root knot control, but the longer rotations are more reliable. If the grower will plant his black shank infected land to other crops for only 2 or 3 years, he may sometimes be benefited by this shorter rotation.

The point is that the 5- to 6-year rotations here recommended for black shank are the shortest that have been found reasonably safe under average conditions.

Again, many growers will soon be using black shank- and wilt-resistant varieties, and it might be assumed that these will make rotation unnecessary. Preliminary results indicate that this is not true. The new varieties will be resistant but not immune, and they will permit rotations to be shortened but not dispensed with. In the case of black shank it may be practicable to use a resistant variety and a 3-year rotation and in the case of wilt a resistant variety and a 2-year rotation.

ROTATION IN RELATION TO YIELD AND QUALITY

In all the rotation experiments, records were kept of yield of cured leaf in pounds per acre and of quality as price per pound when sold. Yields from most of the legume rotations were consistently higher than those from nonlegumes, the increase averaging about 300 pounds an acre. Tobacco produced in legume rotations was a little lower in quality than in nonlegume rotations, and under some market conditions this difference might result in a materially lower price per pound for tobacco in the legume rotation.

This possibility must be kept in mind despite the fact that the records showed the price paid for tobacco in legume rotations was only slightly lower for the period 1937 to 1942, when the greater yields and the only slightly lower price brought cash returns from legume rotations that generally were decidedly greater. The most outstanding legumes in this respect were crotalaria and harvested peanuts. Excellent results have been obtained with soybeans in North Carolina.

Furthermore, it was found in a number of tests that the quality of tobacco after legumes could often be improved by reducing the nitrogen in the tobacco fertilizer by as much as half that ordinarily recommended and increasing the phosphate and potash. This is a very important consideration when the available commercial nitrogen is limited. Since nitrogen supplied by legumes is organic, it is important that the nitrogen in the fertilizer be inorganic, such as nitrate of soda.

Finally, as with all phases of tobacco culture, it is to be emphasized that rotation and the use of legumes is a matter requiring good judgment. If the land is thin and sandy, a crop of crotalaria turned under and followed the next year by flue-cured tobacco may give excellent results, but on more fertile land it would be better to grow the crotalaria 2 years ahead of tobacco.

It is also to be kept in mind that if only such crops as crotalaria are grown for long periods in tobacco rotations, the soil, even if thin and sandy, may eventually be improved to the point where good leaf quality cannot be produced because of excessive nitrogen.

Again, Spanish peanuts, harvested, return much less nitrogen to the land than runner peanuts. Consequently, when peanuts are to precede tobacco, the Spanish type should be used and harvested so as to remove both vines and nuts.

Flue-cured tobacco grown after legumes produces less of the lug and more of the leaf grades, which may be of importance, depending on the market situation and the differences in price between grades.

SUMMARY OF ROTATION RECOMMENDATIONS

Growers can use crop rotation for disease control in two ways: (1) They can wait until a field becomes seriously diseased and then rotate to bring the disease under control; or (2) they can observe disease developments more closely and practice rotation with a view to keeping their fields healthy. The second method is both easier and less costly. A summary of the rotation results from many experiments is given in table 1.

TABLE 1.—*Summary of rotation recommendations for disease control in flue-cured tobacco*

[Resistant crops, indicated by "Yes," should be grown 4 years or more to control black shank, 2 or 3 years to reduce bacterial wilt, and 2 years to prevent excessive root knot. Nonresistant crops are indicated by "No"]

Rotation crop	Suitable for use on land affected by—			Remarks
	Black shank	Bacterial wilt	Root knot	
Corn	Yes	Yes	No	Best for wilt; excellent leaf quality.
Cotton	Yes	Yes	(2)	Excellent leaf quality.
Cowpeas [1]	Yes	Yes	No	Nematode-resistant peas unsafe for root knot.
Crotalaria [1]	Yes	Yes	Yes	Excellent for root knot; fair to good leaf quality.
Lespedeza [1]	Yes	Yes	No	Poor leaf quality usually, but fair to good on poor, sandy soil.
Oats, rye, or wheat	Yes	Yes	Yes	Oats and rye also good winter cover crops; excellent leaf quality.
Peanuts—Spanish (harvested)	Yes	No	Yes	Excellent for root knot; fair leaf quality.
Peanuts—runner [1]	Yes	No	Yes	Excellent for root knot; poor leaf quality.
Pepper or potato (Irish)	No	No	No	Not recommended in rotation.
Redtop	Yes	Yes	Yes	Good leaf quality.
Soybean [1]	Yes	Yes	No	So-called nematode-resistant soybeans not safe for root knot.
Sweetpotato	Yes	Yes	No	Not recommended in rotation, because of fusarium wilt as well as root knot.
Tomato	No	No	No	Not recommended in rotation.
Velvetbean [1]	Yes	Yes	(2)	Very poor leaf quality.
Weeds	Yes	No	Yes	Excellent leaf quality.

[1] Crop may add too much nitrogen for flue-cured tobacco, especially on fertile land and where crop residues are not removed. It may be included to best advantage when grown 2 years in advance of tobacco and when nonlegumes are planted in between.

[2] Cotton and velvetbeans often are safe except in heavily infected root knot soils. They should not be included in root knot rotations except occasionally. Include in 3-year rotations, the more resistant crop preceding the tobacco.

Irish potatoes, tomatoes, and peppers present such a disease hazard to tobacco that they should never be included in a tobacco rotation. Sweetpotatoes, though not affected by black shank or bacterial wilt, are so dangerous from the viewpoint of fusarium wilt and root knot that this crop also should not be grown on tobacco land. It will be noted that some of the very best crops for disease control are listed in the table as producing tobacco of fair or poor quality; for example, crotalaria and runner peanuts. This is true, however, only when these crops immediately precede the tobacco. These unfavorable effects can be completely eliminated by growing another crop, as oats, between the crotalaria or runner peanuts and the tobacco. Thus setting up a successful disease-control rotation involves (1) identification of the disease, (2) selection of resistant crops well adapted to the farm and locality, and (3) effective arrangement of the crops in the rotation.

U. S. GOVERNMENT PRINTING OFFICE: 1944